Hanford 200 Areas Spectral Gamma Baseline Characterization Project
Hanford Project DOE-RL Annual Report for FY 2002

S.M. Stoller Corp., November 14, 2002

The Hanford 200 Areas Spectral Gamma Baseline Characterization Project is operated for the Department of Energy Grand Junction Office (DOE-GJO) by the S.M. Stoller Corporation (Stoller). This project provides geophysical logging services at the Hanford Site to both the DOE Richland Operations Office (DOE-RL) and Office of River Protection (DOE-ORP). These services primarily consist of high-resolution spectral gamma logging and neutron moisture logging in existing boreholes in the Hanford 200 Areas.

The project operates two specially configured logging systems designed to collect high-resolution gamma energy spectra *in situ*, using liquid nitrogen cooled high-purity germanium (HPGe) detectors. These systems, referred to as spectral gamma logging systems (SGLSs), can detect and quantify natural and man-made radionuclides from background levels up to a maximum activity on the order of 5,000 to 10,000 picocuries per gram (pCi/g) cesium-137 (^{137}Cs). Another much smaller detector operated on the same logging system constitutes the high rate logging system (HRLS). The HRLS is specifically designed to operate in zones of high gamma flux where the SGLS cannot function. Using internal and external shields, the HRLS extends the measurement capability to about 10^9 pCi/g ^{137}Cs. Both the SGLS and the HRLS are annually calibrated to provide reliable detection and quantification of gamma-emitting radionuclides. A neutron moisture gage is also available. The neutron moisture logging system (NMLS) is calibrated to provide an indication of the volumetric moisture content up to about 20 percent in 6-inch- and 8-inch-diameter cased boreholes.

Major characterization activities in fiscal year (FY) 2002 included the following:

Contract Transition

As a result of the award of the Grand Junction Technical Support Contract to Stoller, responsibility for vadose zone logging and monitoring activities was transferred from MACTEC-ERS to Stoller on July 21, 2002. Most project personnel were transferred from MACTEC-ERS to Stoller and the work continued without interruption, using office space and computers leased from MACTEC, Inc. Beginning in FY2003, Stoller will be responsible for all geophysical logging at the Hanford Site. This will allow logging activities to be integrated across multiple organizations and projects with consistent procedures and known data quality. Logging equipment previously used by other organizations will be transferred to Stoller.

Vadose Zone Characterization in Hanford 200 Area Waste Sites

In FY2001, work began to extend the existing vadose zone characterization baseline developed for the 12 single-shell tank farms into the waste disposal sites in the Hanford 200 Areas, using the equipment and methods developed for the tank farms baseline characterization project. The goal of the characterization project is to obtain consistent spectral gamma logs of known data quality from existing boreholes and to identify and quantify natural and man-made gamma-emitting radionuclides in the vadose zone. This information can be used to identify stratigraphic

boundaries and to determine the nature and extent of subsurface radioactive contamination associated with Hanford operations. The characterization data also provide a baseline of known quality against which future measurements can be compared to assess the stability or mobility of subsurface contaminant plumes.

In addition to approximately 800 existing boreholes identified in the *Hanford 200 Areas Vadose Zone Characterization Plan* (DOE 2001a), spectral gamma logging is performed in new boreholes drilled for waste site investigations and in most new RCRA groundwater monitoring wells. During FY2002, characterization logging was completed in 70 existing boreholes. A total of 9 new boreholes were logged in support of ongoing remedial investigation projects. Log Data Reports and log plots from existing boreholes were also provided to remedial investigation projects and some existing boreholes were logged at the specific request of remedial investigation projects. Spectral gamma logging was also performed in 5 RCRA groundwater monitoring wells constructed during FY2002, and in 3 boreholes associated with the intermediate and low-activity waste (ILAW) site. Finally, spectral gamma logging was performed in 4 tank farm monitoring boreholes to investigate anomalies detected by the monitoring program. High-rate logging was performed in 23 boreholes. Moisture logging was performed in various boreholes in response to specific requests.

Log plots and Log Data Reports are prepared for each borehole. During FY2002, the Data Analysis Manual (DOE 2002c) was extensively revised to utilize Excel workbooks for log analysis. Spectral analysis is performed to identify individual energy peaks and determine net count rate. Individual energy peak data are concentrated into data files using in-house software and imported into Excel, where the calibration function, dead time correction, casing correction, and water correction are applied to determine concentration (specific activity). The primary advantage of Excel is that the calculations are easily traceable, and greater flexibility is provided for dealing with variable borehole conditions. In addition, Excel files represent a universal format that can be transmitted to others. Preliminary log plots can be made in Excel, but the data are imported into SigmaPlot for final plots. The final log plots and the Log Data Report are converted to Adobe Acrobat (*.PDF) files to facilitate electronic transmittal, allowing log data to be widely distributed via electronic media. All log data, log plots, and reports are accessible via the Internet at:

http://www.gjo.doe.gov/programs/hanf/HTFVZ.html

The project web pages are updated on an on-going basis to include current log results, Waste Site Summary Reports, and quarterly and annual tank farm monitoring reports, as well as previous vadose zone characterization data and reports for the Hanford single-shell tank farms.

In addition to existing and new boreholes logged for others, the baseline characterization plan (DOE 2001a) provides a prioritized borehole listing and identifies waste sites and areas for which baseline characterization logging is to be performed. When all available boreholes in a specific area have been logged and evaluated, a Waste Site Summary Report is prepared. These reports consolidate information from individual baseline spectral gamma logs, other available borehole logs and driller's reports, geologic data, sample data, and operational history to

summarize vadose zone contamination conditions. Where appropriate, data from the tank farms baseline are incorporated, and subsurface visualizations are prepared. During FY2002, Waste Site Summary Reports were issued for the 216-B-35 to B-42 Trenches (DOE 2002a) and the 216-B-8 Crib and Adjacent Areas (DOE 2002b), and a Waste Site Summary Report for the 216-B-5 Injection Well and adjacent sites was in progress. Additional Waste Site Summary Reports are planned for the 216-B-43 to -B-50 and -B-57 Cribs (also known as the "BY Cribs") and the 216-B-61 Crib. When these reports are completed, a more comprehensive report will be prepared to integrate results across the B/BX/BY Waste Management Area.

Preparation of future Waste Site Summary Reports will depend to some extent on the progress of remedial investigation work by other Hanford contractors in the 200 Areas. Much of the remedial investigation work is being carried out under the "analogous site" concept (DOE 1997), wherein waste sites are clustered by function and type of waste, and only a few sites are investigated in detail, under the assumption that other sites with similar history and conditions will have similar contamination conditions. Site investigation under this approach requires geophysical logs from relatively few boreholes from a wide variety of scattered sites and does not integrate well with the detailed evaluation of all available log data within a limited area. In general, priority will be given to logging new and existing boreholes in support of ongoing remedial investigation and monitoring programs. Other boreholes will be logged as time permits and Waste Site Summary Reports will be prepared when all available boreholes in a specific area have been logged. The sequence scope and schedule of individual Waste Site Summary Reports will continually be adjusted to take advantage of logging performed in support of remedial investigations and to integrate the baseline characterization into the overall remedial effort. When completed, the Waste Site Summary Reports are issued in paper copy, on CD-ROM, and on the project web site. All supporting data are included as appendices on the CD-ROM and on the web site. This approach greatly reduces the cost of report preparation and provides a means for wide distribution of the report and supporting data.

Recommendations for Future Work

Recommendations for future work can be subdivided into several general areas:

- Consolidation of Geophysical Logging Capability
- Baseline Characterization Enhancements
- Data Interpretation Enhancements
- Expansion of Logging Capability

Each of these topics will be discussed in greater detail in the following sections.

Consolidation of Geophysical Logging Capability

Per DOE-RL directive, GJO/Stoller will be responsible for all borehole geophysical logging at the Hanford Site beginning in FY2003. Logging equipment formerly operated by others has been or soon will be transferred to Stoller custody. To avoid confusion, logging systems are identified in terms of the individual sonde and surface logging system. Each logging system and sonde are designated by a unique identifier, and the first two characters of each data file name identify the combination of logging system and sonde with which it was collected. Table 1 (attached) identifies specific logging system combinations currently available and indicates the next calibration date for each logging system.

Baseline Characterization Enhancements

- **Develop spectral gamma logging capability for small diameter (less than 4 inches) boreholes**. This capability is necessary because the high cost of drilling has led to an interest in direct push technology, such as the cone penetrometer or the GeoProbe. Although there are a number of obstacles to widespread implementation of direct push technology in the geologic conditions encountered at Hanford, direct push technology will have at least a limited role in shallow subsurface investigations. The diameter for logging in direct push investigations is generally 2 inches or less.

- **Identify new software for analysis of gamma energy spectra**. The software currently used for evaluation of gamma energy spectra is obsolete and no longer supported. In the meantime, computer capability has improved considerably. In the near future, the project should conduct a review of available software for gamma energy spectra analysis, taking into consideration improvements in capability and processing speed, as well as compatibility with existing data files and acceptance by the scientific community. The existing software is still functioning, but it must be recognized that it cannot be upgraded and will eventually need to be replaced.

- **Modify data collection parameters to expedite logging**. Existing boreholes around the liquid waste disposal sites exhibit a wider variety of casing configuration and wall thickness than was encountered in the tank farms drywells, and new boreholes are commonly drilled using thicker casing. Total casing wall thickness of more than 0.5 inch is not uncommon. To achieve reliable data quality, a longer count time is required at each measurement point in these boreholes. However, this extends the time required to complete the log. The typical method is to hold the sonde stationary for a 100-second count time at depth intervals of 0.5 ft. In thicker casing, the count time is increased to 200 seconds. Experience with the spectral gamma log has shown that the depth interval can be increased to 1.0 foot for routine measurements, without the risk of entirely missing thin zones of contamination. Therefore it is recommended that the routine log parameters be modified to a 100-second count time at 1-foot intervals where casing thickness is less than 0.33 inch, and a 200-second count time at 1-foot intervals for casing thickness greater than 0.33 inch. If necessary a repeat section can be run at 0.5-foot depth intervals to achieve greater detail. This approach will avoid increasing the logging time in

boreholes with thick casing while offering a time savings in boreholes with conventional casing.

Data Interpretation Enhancements

- **Continue nuclear transport model studies to support enhancements to shape factor analysis**. The concept for Dr. R.D. Wilson's shape factor analysis (DOE 1997) is scientifically sound, but evidence from logs acquired over the years hints that numerical factors derived by Wilson and used for shape factor interpretation may be inaccurate. If true, these inaccuracies impact not only the gamma source distribution interpretations, but also identification of strontium-90 (^{90}Sr). Dr. Wilson's results were based on modeling with an older and less sophisticated version of MCNP. DOE-GJO possesses an improved version of MCNP and more powerful computers that will generate more precise results. The model results should lead to greater reliability in the shape factor analyses and adaptation of shape factor analysis to a wider range of casing diameters and thickness. In addition, extension of the MCNP simulations to neutron-neutron measurement might permit estimation of correction factors for borehole diameters and casing thickness that are currently unattainable.

- **Implement spatial deconvolution methods to improve evaluation of thin beds**. A major improvement in spatial resolution can be gained by a data processing method known as spatial deconvolution. The method is strictly a data processing technique; it will not involve hardware acquisition or modifications to the existing logging equipment. Spatial deconvolution was perfected for the gross gamma log in the 1970s by Drs. J.G. Conaway and P.G. Killeen. An analogous method for specific spectral line intensities has not been developed. The data required to develop the method are already in hand.

Expansion of Logging Capability

- **Expand neutron moisture logging capability**. In the past, neutron moisture logs have infrequently been run for special purposes. However, neutron moisture logs have been shown to be useful as a stratigraphic correlation tool. There is also a growing emphasis on neutron moisture monitoring to support tank farm retrieval operations. Moreover it is generally recognized that variations in subsurface moisture and migration of moisture in the vadose zone are controlling factors in contaminant migration. A "baseline" of neutron moisture measurements would be helpful in identifying zones of anomalous subsurface moisture and probable contaminant migration. One of the recently acquired logging vehicles (RLS-3) is not suitable for use with the HPGe detectors. It could be configured primarily for neutron moisture logging and used in conjunction with the SGLS in the characterization program. In general, because variations in moisture are of more interest than absolute values, the logs could be used semi-empirically with no need to develop additional calibration models.

- **Develop neutron capture logging**. At GJO, Dr. Carl Koizumi has developed an innovative data analysis technique that should provide calibrated neutron capture assays

under nearly all logging conditions. This method is capable of compensating for variations in the neutron source output or neutron moderating/absorption properties of the medium. Under Dr. Russel Hertzog, the INEEL Subsurface Science Initiative is developing neutron capture logging sondes. It should be possible to integrate Dr. Koizumi's analytical technique with the INEEL hardware to provide a method for *in situ* assessment of certain non-radioactive elements in subsurface from measurements in cased boreholes. Neutron capture logging has been attempted at Hanford in the past as a means to detect chlorinated compounds, but this work was not successful. The failure of neutron capture logging was due in large part to a lack of understanding of the differences between measurement in the vadose zone and typical logging conditions. We believe that neutron capture logging can detect nitrogen as a signature of tank waste (which is primarily sodium nitrate), and that calcium, magnesium, sodium, and potassium can be logged as lithologic indicators.

References

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Attachment
Logging Sondes and Vehicles (Nov. 2002)

Table 1. Logging Sondes and Vehicles (Nov. 2002)

Designation				**Logging System (Vehicle)**				
New	**Old**	**Type**	**Serial No.**	**A** Gamma 1 HO 68B-3574	**B** Gamma 2 HO 68B-3572	**C** RLS-1[1] HO 68B-4330	**D** RLS-2[2] HO 68B-3573	**E** RLS-3[3] HO 68B-391
A	ϒ1A	SGLS 35%	34TP20893A		**BA** (Oct 2003)			*NA*[4]
B	ϒ1/2B "spare"	SGLS 35%	36TP21095A		**BB** (Oct 2003)			*NA*
C	ϒ1C	HRLS	39A314	**AC**[5] (Feb 2003)	*NA*	*NA*	*NA*	*NA*
D	ϒ2A	SGLS 35%	34TP11019B	**AD** (Oct 2003)				*NA*
E[6]	RLS-1	70% HPGe	34TP40587A	*NA*	*NA*	**CE** (Oct 2003)		
F		NMLS	H380932510		**BF** (Oct 2003)			EF
G		SGLS 35%		AG ?		CG ?	DG? ?	*NA*
H		NMLS	D72024328					EH
I		10% HPGe						
J		18% HPGe	32TP10832A					
K		20% HPGe	34TN11004A					
L		^{3}He	U1754					

[1] RLS-1 will be primarily used to run the 70% HPGe detector (E) in RCRA wells.
[2] RLS-2 will be acquired from Duratek and configured as a third SGLS vehicle.
[3] RLS-3 will be acquired from Duratek and configured primarily for neutron moisture logging.
[4] Indicates this combination is not available due to incompatability.
[5] The HRLS requires a special verifier that is permanently mounted on Gamma 1.
[6] This sonde is primarily intended for RCRA groundwater well logging.